# Challenges to Building Clean Coal Plant in Western U.S.

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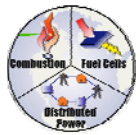


# The Challenge

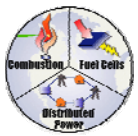
- Not so much whether Clean Coal Technology Available
- But What is Appropriate Technology?
  - IGCC or Boiler / Type
  - Which Technology Results in
    - Lower COE
    - While in Environmental Compliance Consistent with “Design Criteria”
  - If $CO_2$ Capture Required
    - Finding Home for Captured $CO_2$
- Need Design Criteria for “Clean” Coal Plant
  - Define Environmental Criteria - How Clean is “Clean”?
  - Define Economic Criteria - How Much are we Willing to Pay?

# IGCC or Boiler?

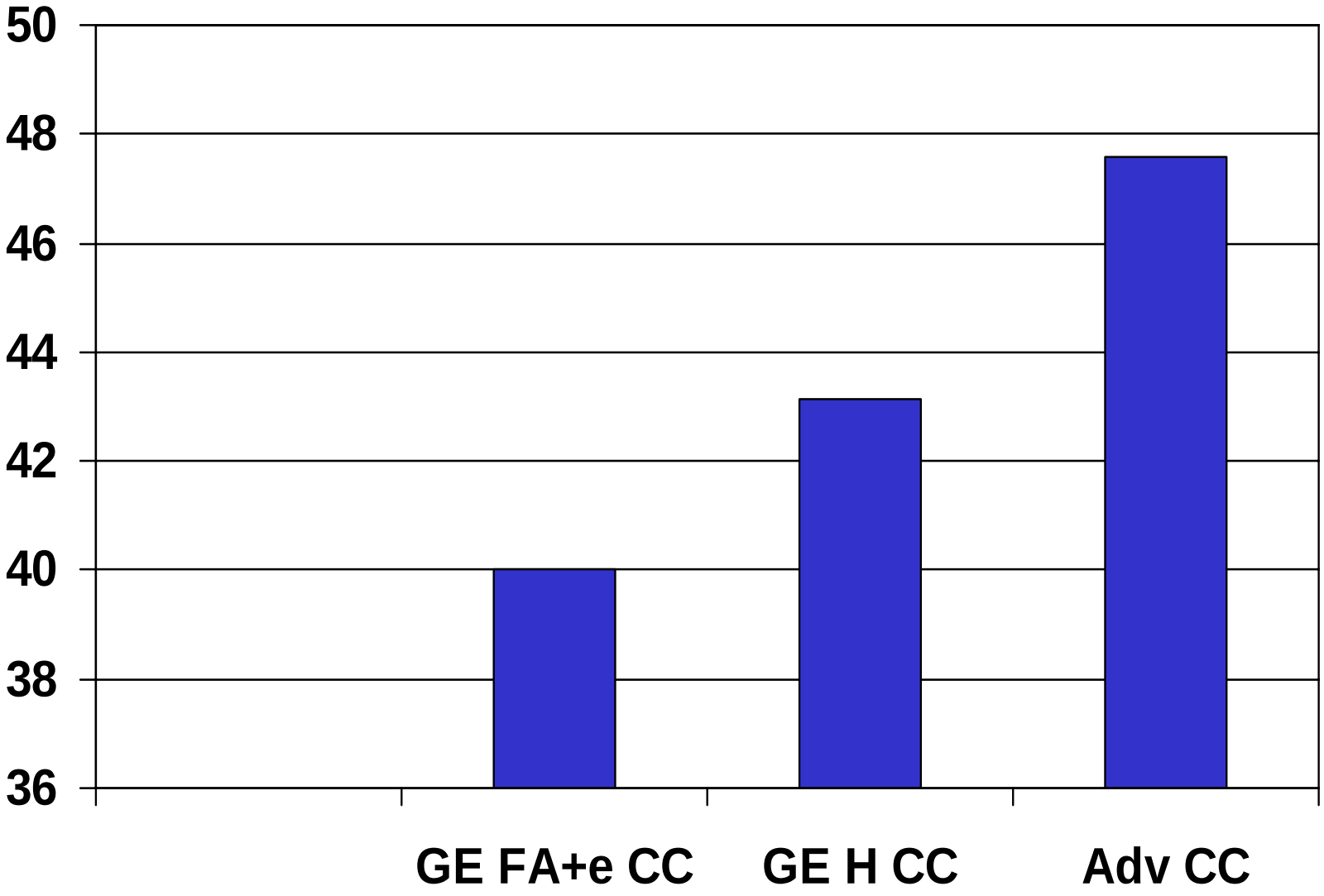
- Answer not Simple
- Depends Primarily on Emissions Limits / Coal / Location
  - Coal
    - Rank (Black Mesa or Utah Coals vs. PRB Coal)
    - Ash Content & its Properties
    - Moisture Content (especially for Slurry Fed Gasifiers)
  - Location
    - Elevation
    - Availability of Water
    - Mode of Heat Rejection
- & Whether Market Exists for a Coproduct
  - Example: $H_2$
- Difficult to Generalize
  - IGCC on Higher Rank Coals (or Lower Rank Coals + Pet Coke)
    - Costs Generally Competitive
    - If Environmental Constrains Very Stringent
  - Coproduction, a Special Advantage for IGCC

# IGCC Technology

- Gasification Technologies Suitable to Higher Rank Coals
  - GE & E-Gas
    - Sensitive to Specific High Rank Coal, e.g., Pittsburg 8 vs Illinois 6
    - If Plant Built in Nevada
      - Transport Black Mesa as Slurry
      - Natural Fit for Slurry Fed Gasifiers
  - Shell
    - Design Improvements being made to Reduce Costs
  - BGL
    - Limited Experience
- Gasification Technologies Suitable to Low Rank Coals
  - Lurgi
    - Complex due to Tars/Oils & Can Handle Limited Amounts of Fines
  - HT Winkler
    - Limited Experience
  - ATR
    - Very Promising
    - Southern Company & Orlando Utilities Commission to build 285 MW IGCC near Orlando, Florida
- Timing of Project - Future Looks Good
  - Cost Reduction by Developing Standard Plant Designs
  - Improved Performance with Higher Firing Temp GTs (H technology / Reheat GT)
  - Increasing Power Block Efficiency Reduces Cost ($/kW) of IGCC



# IGCC Relative Efficiency Trends (% Coal HHV)



# IGCC Environmental Signature

- Sulfur
  - Captured as Saleable Byproduct
  - Capture > 99% w/o Significant Increase in Cost
- Heavy Metals
  - Commercially Proven for Capture of Hg & As (> 95%)
    - Same Sulfided Activated Carbon Expected to Capture Se & Cd
    - Cost Low due to Small Volume of Gas Treated
- NOx
  - 15 ppmV (15% $O_2$, Dry) w/o SCR
  - Ultra Low with SCR - Negishi Plant in Japan
- Particulate Emissions
  - Wabash IGCC < 0.012 lb/MMBtu or 0.088 lb/MWh

# IGCC Environmental Signature (Cont'd)

- Water Usage
  - Lower Consumption
  - Performance Degradation Lower when Air-cooled
- Solids Waste
  - Less Produced (Compared to FGD with Limestone)
  - Vitrified Form
- $CO_2$ Capture
  - Low Incremental Cost of Capture
  - Captured from Syngas with high $CO_2$ Partial Pressure
  - Bulk of $CO_2$ regenerated at High Pressure
  - Captured in AGR for Syngas Sulfur Removal

# Boiler Technology

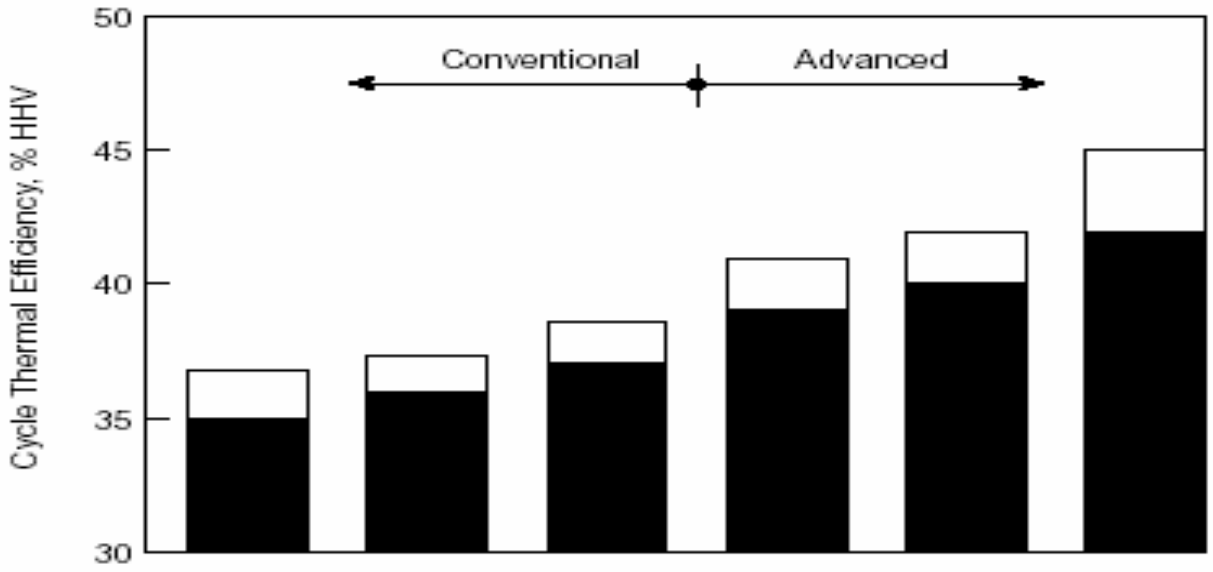
## Pulverized Coal

- Supercritical Units Commercialized about 45 years ago
- A Mature Technology
  - Current Availabilities ≈ Sub-critical Units
- Typically Lower Plant Cost than IGCC
  - Especially for Lower Rank Coals
  - But Need Detailed Analysis in “Clean Coal” Applications

## Fluidized Bed

- Currently Offered Max Size: 300 to 400 MW
- Larger Sizes being Investigated
  - Application of Super-critical Steam Cycle Possible
    - Lower & Uniform Bed Temp Helpful to Water Wall Enclosing Bed
    - But Increases Heat Transfer Surface
- Suitable for Difficult to Burn Fuels
- Fuel Flexibility
  - Brown Coals
  - Anthracite
- Generally Lower Environmental Emissions Compared to PC
  - Lower NOx due to Lower Temp
  - Upto 98% In-bed Sulfur Capture with Limestone

# Boiler Plant Efficiency Trends (Source: B&W)




| | | | | | | |
|---|---|---|---|---|---|---|
| Pressure, psi | 2400 | 3500 | 3500 | 4500 | 4500 | 6000 |
| SH Temp, F | 1000 | 1000 | 1000 | 1050 | 1100 | 1200 |
| RH Temp, F | 1000 | 1000 | 1025 | 1050 | 1100 | 1200 |
| 2RH Temp, F | — | — | 1050 | 1050 | 1100 | 1200 |
| Pressure, bar | 16 6 | 24 1 | 24 1 | 31 0 | 31 0 | 41 4 |
| SH Temp, C | 538 | 538 | 538 | 566 | 593 | 649 |
| RH Temp, C | 538 | 538 | 552 | 566 | 593 | 649 |
| 2RH Temp, C | — | — | 566 | 566 | 593 | 649 |

1. Current State-of-the-Art: 290 bar / 580ºC / 600ºC or 4200 psi / 1080ºF / 1110ºF
2. European Thermie Project: 375 bar / 700ºC or 5440 psi / 1290ºF; $\eta_{HHV}$ > 45%; 2008 Demonstration

# Boiler Cleanup Technologies also Evolving

- FGD
  - CANSOLV
    - Captured / Regenerated as $SO_2$ by Amine Solvent
    - Produce $H_2SO_4$ as Saleable Product
- NOx
  - BOC's LOTOx
    - $O_3$ Oxidizes NOx to Soluble Species ($N_2O_3$ & $N_2O_5$)
- Particulates
  - EPRI's COHPAC
    - Combination of ESP and Baghouse
- Hg
  - Alstom's Filsorption
    - Extensive Experience in Waste to Energy Plants
    - Removes > 85% of Elemental Hg & > 90% Oxidized Hg
  - EPRI's TOXECON
    - Demonstrated on Existing Coal Plants
    - Removed ~ 90% of Hg
- $CO_2$ Capture
  - Amine Wash of Flue Gas
  - Limited Experience on Coal derived Flue Gas

# Summary

- **No Simple Answer for Picking Appropriate Technology**
  - "Clean Coal Technologies" are Available
  - IGCC is Very Clean
  - Challenge: How Much are we willing to Pay

- **Necessary 1st Steps**
  - Establish Design Criteria
  - Perform Detailed Techno-Economic Evaluation
    - Specific Coal(s), Site(s) & Environmental Constraints
    - Factor in Lessons Learnt into Conceptual Design
    - Compare Technology Options on Consistent Basis
      - With Similar Commercial Guarantees
        - Experience with / Applicability to Particular Coal & its Trace Components
      - Assess Commercial Experience in Integrated Designs
        - Compatibility of Downstream Unit with Upstream Unit